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Introduction

A large form of industrial waste known as coal ash is produced by coal-burning power plants, containing specific elements known as trace metals at ppm or ppb concentrations. Upon coal combustion, this ash undergoes a variety of treatments such as filtration, pH adjustment, etc. These treated leachates then get stored in lined or unlined coal ash ponds, leading to the leaching of trace metals into the surrounding environment. Coal-burning power plants can also directly discharge their treated coal ash waste into nearby water ways via pipes that are connected to their coal ash ponds under the EPA's NPDES discharge permit (NPDES Permit Basics, 2019). Once mixed with water, the associated trace metals are known to leach into solution and enter aquatic environments (Lokeshappa and Dikshit, 2012). Previous studies have mainly focused on 1) the ability of trace metals to leach from coal ash, 2) specific trace metals that are commonly found within coal ash, and 3) the bioaccumulation of trace metals within aquatic organisms. Few studies have been conducted on the presence of trace metal contamination within environmental samples collected near an active coal-burning repository within the Chesapeake Bay region.

Objectives

- Assess the spatial and temporal distribution of trace metal contamination in sediment and water samples collected from around a coal-burning power station located within the Chesapeake Bay region: Chesterfield power station.

Hypotheses

- In water column samples, trace metals were expected to be found in higher quantities closer to the sediment than samples closer to the surface.
- In grab samples, trace metals were expected to be found in higher quantities in samples collected adjacent to and downstream of the power station due to water flow.
- In sediment cores, trace metals were expected to be found in higher quantities closer to the top of the sediment core within the younger sediment due to recent power station activity.

Materials and Methods

Field Sampling

- Sediment and water samples were collected along the James River, Virginia, USA (Chester, VA) (Figure 1). Sediment cores were collected using a manual push coring device (Figure 2). Water column samples were collected using a Wildco water sampler and dip sampling.
- Individual sediment core samples (2 cm intervals) and grab samples were dried at 100°C, sieved through 63µm sieve, and digested in 3:3:1 ratio of aqua regia [43 mL of nanopure ultra-deionized H_2O (>18 MΩ per cm): 43 mL of HCl: 14 mL of HNO_3].
- Sediment samples were then filtered and analyzed for trace metal contamination using ICP-OES (Table 1; Graphs 1-6; Figure 3).
- Water samples acidified using 10% HNO_3 to prevent the adherence of trace metals to the container and then filtered to remove any particulates.
- Water samples were analyzed for trace metal contamination using ICP-OES (Table 1; Figure 3).

Results

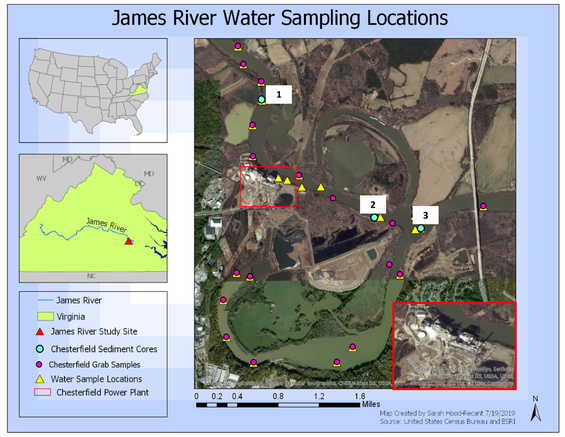


Figure 1 – GIS map displaying sampling locations at Chesterfield power station along the James River for sediment cores, grab, and water samples. Created by Sarah Hood-Recant.

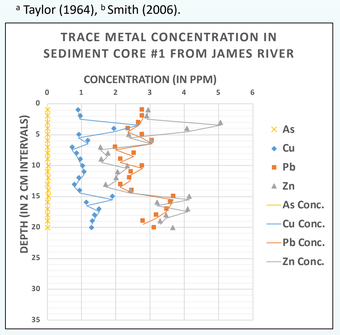
Figure 2: Extraction of sediment core from the James River.

Figure 3: ICP-OES used for trace metal analysis.

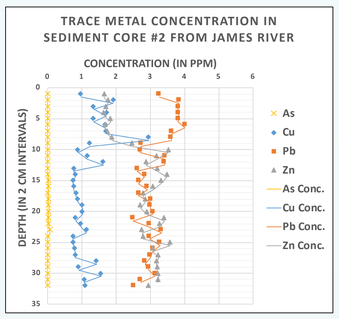
Table 1: Mean metal concentration in Earth's crust, Virginia soils, and all of the sediment cores used in this study (ppm, except for Al, Ca, Fe, Mg).

	Al %	As	Ca %	Cd	Cr	Cu	Fe %	Mg %	Mn	Pb	Se	Zn	# Samples
Avg Crust[a]	8.23	1.8	4.15	0.2	100	55	5.63	2.33	950	12.5	0.05	70	N/A
Virginia Soils[b]	4.14	4.6	0.27	0.04	16.01	6.5	1.4	0.21	1007	34	1.2	29	N/A
L-1 (Upstream)	3.43	0.005	1.48	0.02	1.01	1.22	12.55	0.87	22.04	2.75	0.35	2.88	20
Grab (Upstream)	3.58	0	1.12	0	N/A	2.54	11.44	1.05	23	1.5	0.42	3.03	5
L-2 (Adjacent)	4.35	0.01	1.21	0.02	1.34	1.17	15	0.99	20.99	3.13	0.48	2.76	23
Grab (Adjacent)	3.65	0	1.36	0	N/A	2.27	11.66	1.06	28.22	1.48	0.4	2.93	1
Water (Adjacent)	0	0	0.17	0.01	N/A	0.01	0	0.03	0	0	0	0.43	6
L-3 (Downstream)	3.82	0.009	1.15	0	1	1.27	12.08	0.97	26.27	1.06	0.3	3	32
Grab (Downstream)	3.8	0.02	1.25	0	N/A	1.67	12.12	1.03	41.08	1.63	0.46	2.94	3
Water (Downstream)	0	0	0.2	0	N/A	0.01	0	0.04	0	0	0	0.43	3
Grab (Behind)	3.99	0.04	1.04	0	N/A	2.2	13.09	1	27.84	1.85	0.51	3.86	9
Water (Behind)	0	0	0.21	0	N/A	0	0	0.04	0	0	0	0.43	22

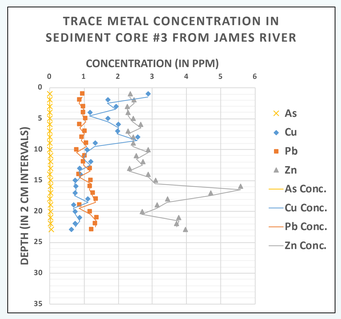
[a] Taylor (1964), [b] Smith (2006).



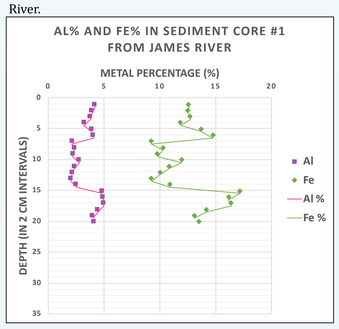
Graph 1: Trace metal concentration in sediment core collected from Location #1 (upstream) in the James River.



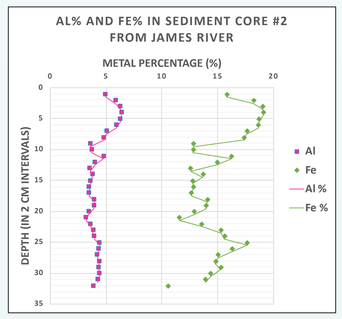
Graph 2: Trace metal concentration in sediment core collected from Location #2 (adjacent) in the James River.



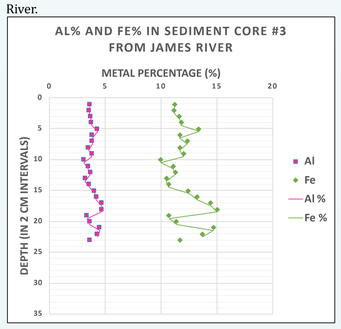
Graph 3: Trace metal concentration in sediment core collected from Location #3 (downstream) in the James River.



Graph 4: Percentage of Aluminum (Al) and Iron (Fe) in sediment core collected from Location #1 (upstream) in the James River.



Graph 5: Percentage of Aluminum (Al) and Iron (Fe) in sediment core collected from Location #2 (adjacent) in the James River.



Graph 6: Percentage of Aluminum (Al) and Iron (Fe) in sediment core collected from Location #3 (downstream) in the James River.

Results (cont.)

Water Samples

- Levels of calcium (Ca), cadmium (Cd), copper (Cu), magnesium (Mg), and zinc (Zn) were found at the highest concentration in the water column samples collected from the bottom of the James River.
- No levels of aluminum (Al), arsenic (As), iron (Fe), or manganese (Mn) were detected in any of the water samples.
- Highest concentrations of trace metals in water samples were found behind Chesterfield power station near Dutch Gap Conservation Area.

Sediment Cores

- Cu and Zn experienced a high increase in concentration within the 6-8 cm interval at the top of core #1 (Upstream)
  - Levels of iron mimic concentration of Pb and Zn.
- Cu and Zn experienced a high increase in concentration within the 14-16 cm interval at the top of core #2 (Adjacent)
  - Pb experienced a high decrease in concentration within the 8-10 cm interval
  - Levels of iron mimic concentration of Pb through out the core.
- Zn experienced a high increase in concentration within the 32-34 cm interval at the bottom of core #3 (Downstream).
- Levels of aluminum did not mimic the concentrations of the metals within the core.

Conclusions

- Similar trends between trace metals and Fe indicates the precipitation of the trace metals due to the presence of iron oxides (Reduction-oxidation boundary).
- Lower presence of trace metals within sediment cores could be the result of the high presence of water pumps connected to Chesterfield, contributing water and increasing the velocity of water flow.
  - Pushes clay particles (more concentrated) further downstream leaving only mostly sand particles (less concentrated) behind.
- High concentrations of trace metals found near Dutch Gap Conservation Area pose a high risk to people of the community that live near the power station and/or participate in walking on the surrounding trails, and kayaking.

Future Studies

- The next phase of this study will examine sediment samples from behind Chesterfield power station near Dutch Gap Conservation Area.
  - Sediment cores will be obtained from Dutch Gap Conservation Area and analyzed for trace metal contamination via ICP-OES.
  - It is expected that the sediment cores obtained from behind Chesterfield power station will contain higher quantities of trace metals compared to sediment samples collected on the James River based off of preliminary data.
- Collect and examine sediment and water samples for trace metal contamination from Possum Point power station in Dumfries, Virginia.

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